THIRD EXPANSION OF HOLY HARAM MAKKAH

Original Ajiad Plant
13,600 tons cooling capacity
- 34 air-cooled packaged reciprocating chillers
- 400 tons capacity each
- Installed 1993
THIRD EXPANSION OF HOLY HARAM MAKKAH

Shamiya Plant
120,000 tons water-cooled
- 24 YORK Titan OM Chillers
- 5,000 tons net cooling capacity each

First Phase: 80,000 tons
- 8 YORK OM – fixed speed
- 8 YORK OM – variable speed

Second Phase: 40,000 tons
- 8 YORK OM – fixed speed

Ajiad Plant Expansion
15,000 tons air-cooled
- 3 YORK OM – variable speed
- 5,000 tons net cooling capacity each

135,000 Tons Total Cooling Capacity
Commissioned in 2015
Ajiad District Cooling Plant

- Located across from the Holy Haram Makkah
- 34 – 400 ton air-cooled YORK reciprocating chillers
- Installed 1993

Mesh floor for air intake (In addition to side wall air openings)
Shamiya District Cooling Plant

- Located less than 2 km from the Holy Haram Makkah
- Designed for 32 X 5000 Ton water-cooled chillers.
  - 24 chillers are installed.
  - 16 chillers are commissioned and in operation
  - 8 chillers not yet commissioned.
  - 8 more chillers to be ordered in future.
- Commissioning was between 2013-2015
Chilled Water Piping from Shamiya Plant – 3D Layout

- Approximately +/- 1.3 km of chilled water piping from Shamiya Chiller Plant to Holy Haram Makkah
Chilled Water Piping from Shamiya Plant – Utility Tunnel

- Approximately +/- 1.3 km of chilled water piping from Shamiya Chiller Plant to Holy Haram Makkah
- Two chilled water loops
- 1200 mm (47.24”) diameter pipes
SHAMIYA PLANT YORK TITAN OM CHILLERS
24 CHILLERS – 5,000 TON EACH – WATER-COOLED

- 13800V / 3ph / 60Hz, 6000 HP motor
- 16 chillers: 13800V / 3ph / 60Hz Solid State Starters
- 8 chillers: High voltage Variable Speed Drives
- Compressor castings with high design working pressure
- Condenser design working pressure >300 PSIG for potential future refrigerant change
- Allen Bradley PLC control panel
- Automatic Tube Brushing system
- Vibration monitoring system for entire driveline
- Seismic spring isolators
Shamiya Plant YORK OM Chillers – Heat Exchangers

- YORK engineered and manufactured heat exchangers
- Customized to meet the unique project applications and requirements
  - ASME code shells
  - Bolt-on marine water boxes
  - Integral sub-cooler in condenser

- TSE (treated sewage effluent) water is used in the condenser loop
- Condenser corrosion/erosion protection:
  - 90/10 CuNi tube materials, 0.035” tube wall
  - CuNi clad tube sheets
  - High performance polymer composite coating and zinc anodes for waterbox protection
Shamiya Plant YORk OM Chillers

Dimensions
- Length = 32 inch (81.3 cm)
- Width = 16 inch (40.6 cm)
- Operating height range = 12-7/32 ~ 12-1/2 inch (31.0 cm ~ 31.75 cm)
- Approximate weight = 1,100 lbs (499 kg)

5000 Ton YORK Titan OM Chiller Installed
Shamiya Plant YORK OM Chillers – Pressure/Enthalpy Diagram

- Two-stage R-134a refrigerant diagram – one stage of Intercooling with subcooling

![Pressure/Enthalpy Diagram](image)

- Condenser
  - 106.91°F (153.92 PSIA)
- Intercooler
  - 69.77°F (85.46 PSIA)
- Evaporator
  - 39.63°F (49.368 PSIA)
- Compressor Discharge
  - 124.83°F (154.67 PSIA)
  - 15642.2 lbs/min
- 2nd Stage Compression
  - 13991.5 lbs/min
- 1st Stage Compression
  - 49.368 PSIA

Refrig Eff (ΔH) = 74.148 Btu/lb
SHAMIYA PLANT YORK TITAN OM CHILLER PERFORMANCE
FIXED SPEED
VARYING ECWT (ENTERING CONDENSER WATER TEMPERATURES)
SHAMIYA PLANT YORK TITAN OM CHILLER PERFORMANCE

FIXED SPEED VS VARIABLE SPEED

VARYING ECWT (ENTERING CONDENSER WATER TEMPERATURES)

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- Fixed speed
- Variable speed

- 95°F ECWT (35°C)
- 85°F ECWT (29.4°C)
- 75°F ECWT (23.9°C)
- 65°F ECWT (18.3°C)
### SHAMIYA PLANT YORK TITAN OM CHILLER PERFORMANCE

#### FIXED SPEED VS VARIABLE SPEED

**VARYING ECWT (ENTERING CONDENSER WATER TEMPERATURES)**

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**Operating cost savings**
SHAMIYA PLANT YORK TITAN OM CHILLER PERFORMANCE
FIXED SPEED VS VARIABLE SPEED
VARYING ECWT (ENTERING CONDENSER WATER TEMPERATURES)

Jeddah, KSA: WB ≤ 75°F all year

Operating cost savings
SHAMIYA PLANT YORK TITAN OM CHILLER PERFORMANCE
FIXED SPEED VS VARIABLE SPEED
VARYING ECWT (ENTERING CONDENSER WATER TEMPERATURES)

Jeddah, KSA: WB ≤ 65°F approximately 40% of the year

Operating cost savings

Capacity (tons)

COP

Operating cost savings

Capacity (tons)

COP
SHAMIYA PLANT YORK TITAN OM CHILLER PERFORMANCE

FIXED SPEED VS VARIABLE SPEED

VARYING ECWT (ENTERING CONDENSER WATER TEMPERATURES)

- Fixed speed
- Variable speed

- ECWT = 85°F (29.4°C)
- Load = 50%
- kW/ton = 0.610
SHAMIYA PLANT YORK TITAN OM CHILLER PERFORMANCE
VARIABLE SPEED REAL WORLD OPERATION

ECWT = 81°F
(27.4°C)

0.571 kW/ton

2472.3 tons
48.6% load
3 CHILLERS – 5,000 TON EACH – WATER-COOLED (RADIATORS)

- 4160V / 3ph / 60Hz, 9000 HP motor.
- 13.8 KV Variable Speed Drives.
- Compressor castings with high design working pressure.
- Condenser design working pressure >300 PSIG for potential future refrigerant change
- Allen Bradley PLC control panel.
- Vibration monitoring system for entire driveline
Ajiad Plant YORK Titan OM Chillers

- Plant YORK Titan OM Chillers
  - 13,600 ton Chiller Plant (34 reciprocating chillers with sound attenuated roof)
  - YORK OM multi-stage compressor driveline skid
  - 13,800V Variable Speed Drive 9,000 Hp
  - Air-Cooled Radiators
Ajiad Plant YORK Titan OM Chillers – Pressure/Enthalpy Diagram

- Three-stage R-134a refrigerant diagram – two stages of Intercooling with subcooling

Evaporator

- 38.98°F (48.74 PSIA)
- Refrig Eff (\(\Delta H\))=73.68 Btu/lb.

Low stage Intercooler

- 70.87°F (87 PSIA)

High stage Intercooler

- 108.36°F (157.25 PSIA)

Subcooling 141°F

Condenser

- 151.4°F (282.57 PSIA)
- 174.96°F (282.57 PSIA)

Compressor Discharge

- 2nd Stage Compression: 17147 lbs/min
- 3rd Stage Compression: 20375 lbs/min

Enthalpy (Btu/lbs)

Pressure (PSIA)
AJIAD PLANT YORK TITAN OM CHILLER PERFORMANCE
FIXED SPEED VS VARIABLE SPEED
VARYING ECWT (ENTERING CONDENSER WATER TEMPERATURES)

Capacity (tons)

COP

kW/ton

139°F ECWT
(59.9°C)
129°F ECWT
(53.9°C)
124°F ECWT
(51.3°C)
118°F ECWT
(48.3°C)
109°F ECWT
(42.8°C)

fixed speed

variable speed
**AJIAD PLANT YORK TITAN OM CHILLER PERFORMANCE**

**FIXED SPEED VS VARIABLE SPEED**

**VARYING ECWT (ENTERING CONDENSER WATER TEMPERATURES)**

- **ECWT = 109°F (42.8°C)**
- **Load = 100%**
- **kW/ton = 0.993**

Graph showing the performance comparison between fixed speed and variable speed chillers with varying ECWT temperatures.
AJIAD PLANT YORK TITAN OM CHILLER PERFORMANCE
VARIABLE SPEED REAL WORLD OPERATION

0.656 kW/ton
5036 tons
97.8% load

ECWT = 111°F (44.0°C)
QUESTIONS?

Amar Farjo
Lead Staff Engineer
Johnson Controls

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(717) 771-6224
## Weather Data – Dhahran, Saudi Arabia (coastal – similar to Jeddah)

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